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Single-dish continuum observing modes with the Noto radiotelescope

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Abstract. We discuss the capabilities of the Noto 32-meter radiotelescope for different acquisition techniques and the problems we faced to optimize the single-dish continuum acquisitions at different frequencies. In particular, we tested the relevance of the choice of the suitable acquisition method for each observing frequency, in order to reach the instrumental thermal noise limit in single-dish observations,

1. Introduction

In the last few years (since 1998) the Noto radiotelescope has been subjected to a series of structural improvements which remarkably increased its potential capabilities as single-dish instrument. In particular, in 2002 the installation of the active surface has been completed and in 2004 a new 43-GHz receiver has been installed in the secondary focus of the antenna. This new setup, together with the favorable meteorologic conditions, allows operation with excellent performance at high frequencies. At the moment, the Noto telescope is one of the few antennas in the world with good performance in the range of frequencies between 22 and 86 GHz.

Starting from March 2004, when the Istituto di Radioastronomia offered observing time for single-dish scientific projects to be carried out with the two radiotelescopes of Noto and Medicina, continuum-mode observations with the Noto telescope have accounted for about 69% of the total single-dish allotted time, whereas 31% of the time was spent on spectral line observations. We can thus expect that the astronomical community will request a large amount of the SRT time for continuum-mode observations.

As the scientific interest in radioastronomy is shifting toward high frequencies (and the SRT will enhance the opportunities of the astronomical community in this sense), we tried to test possible acquisition techniques that could help to reach the best performance in total power observations, with particular regards to high frequency observations. The aim is to allow to start preliminary scientific projects which will then be extended by using the SRT, when it becomes operational. In this perspective we present the actual performance reached by the Noto radiotelescope for different observing modes.

2. Observing modes

We compare the results obtained in observations performed with three different acquisi-

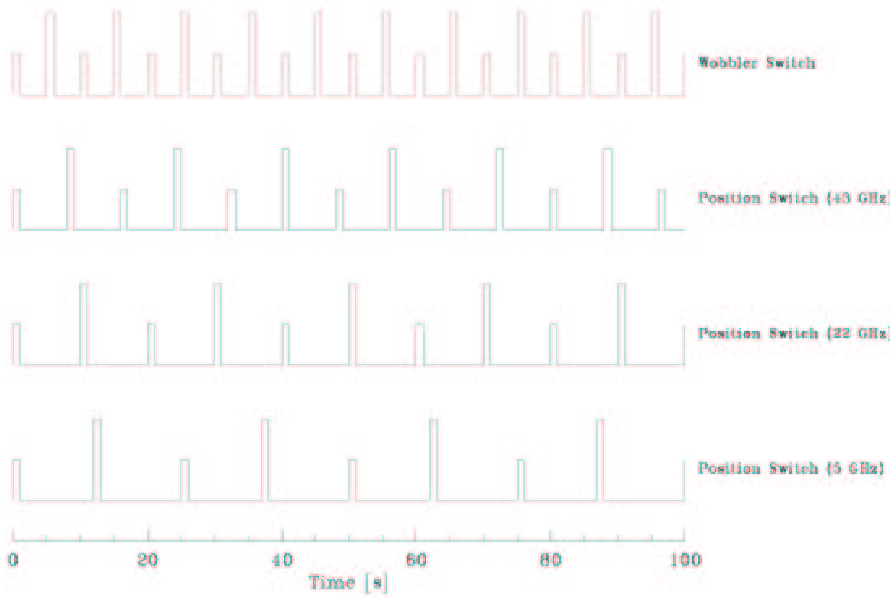

Fig. 1. Comparison between the time required for the ON-OFF duty cycle for the wobbler switch method (top panel) and the position switch method used at 5, 22 and 43 GHz, respectively (middle and bottom panels).

tion techniques, with the aim to verify how the capabilities of the instruments could vary as a function of the observational technique. In particular, we compare the advantages and disadvantages of using the 'wobbler ON-OFF switch' and the 'right ascension drift scan' with the ones of the classical 'position switch', which is performed by moving the entire antenna structure between ON and OFF positions.

2.1. Wobbler Switch

The sub-reflector of the Noto radiotelescope can be tilted in any direction in space by combining translations along the 5 axes of motion (see Orfei et al. 1998 for technical details on the secondary mirror movements). Adopting a proper combination of the allowed sub-reflector movements, the secondary mirror can be wobbled around its focus point along the north-south or east-west directions. This allowed us to implement an observing procedure which switches in azimuth from the source position to a reference position (alternatively on each side of the source) by wobbling the secondary reflector with a specified wobbler throw.

The major advantage of this technique is that the switching time between the ON and OFF position is much shorter than for the classical position switch (Fig. 1), and this is of crucial importance as we move to higher frequencies, as pointed out by Catarzi & Palagi (1989).

As Fig. 1 shows, the duty cycle time for the position switch method increases with the beam size, whereas the duty cycle for the wobbler switch method is independent of the beam size, because the secondary mirror positioning time is much shorter than the communication time between the field system computer and the sub-reflector.

In addition, by adopting the wobbler switch method, the antenna continuously tracks the source, and physical stresses of the entire struc-

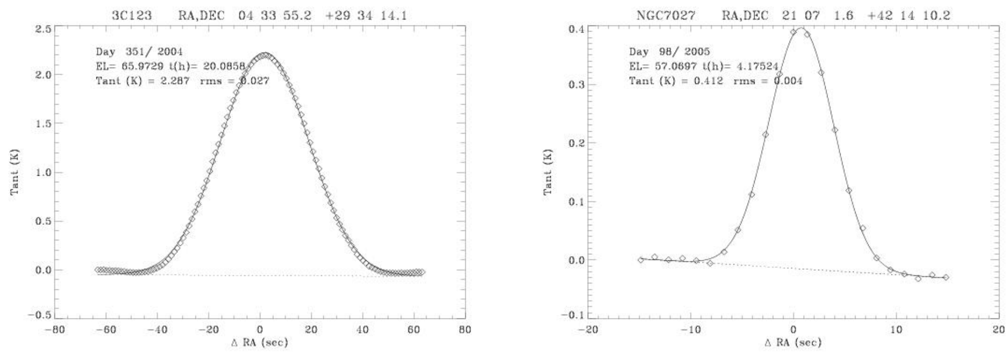

Fig. 2. Examples of drift scans: in the left panel a drift scan at 5 GHz; in the right panel a drift scan at 43 GHz.

ture are limited, since the changes in the pointing position are limited.

The possibility to use this observing mode is, of course, limited to observations performed with receivers located in the secondary focus, that is, for the Noto antenna equipment, the 1.4, 5, 6.7, 22 and 43 GHz receivers.

On the other hand, at the lowest frequencies (in our case 1.4 and 5 GHz) the off-source measurements suffer from the spillover of the secondary mirror onto the warm ground, and consequently the accuracy of the source flux measurement is limited by the accuracy in the estimate of this additional noise term.

2.2. Drift Scan

This mode is used to scan a sky region and collect data while doing it. The radiotelescope is adjusted in elevation to a given angle and the radio source passes through the antenna beamwidth as the Earth rotates. We adopt this mode since, at the moment, our pointing software prevents us to set a velocity in the RA scanning.

Drift scans have the advantage that it is possible to get an accurate measure of the background emission thanks to the ability to perform accurate sky subtractions. For this reason it is a good technique to use when observing confused fields.

On the other hand, the drift time can be longer than the typical time allowed to remain in the white noise regime for radiometers, and therefore this method can be used only for sources easily detectable in short integration times.

The time needed to complete each scan increases with the beam size, so the scan is faster as the frequency increases. Nevertheless it is important to pay attention to the beam sampling: as shown in Fig. 2, an acquisition rate of one point per second provides a good beam sampling at 5 GHz, but at 43 GHz the same acquisition rate gives a poor sampling. For this reason, to perform reliable observations at higher frequencies and/or large dishes, digital integrators that allow high acquisition rates are necessary.

The drift scan technique can be used also to make a map by scanning the area of the sky around a target, at a series of declinations separated by an angle less than the antenna angular beam-width.

2.3. Discussions and Conclusions

In Fig. 3 (left panel) we report three gain curves at 43 GHz obtained by using the position switch, the wobbler switch and the drift scan, respectively. The three gain curves do not show great differences, meaning that the acquisition methods are all good. We notice that, for the measurements performed with the ON-OFF technique, the basic observation duty cycle consisted of 1 second of integration time

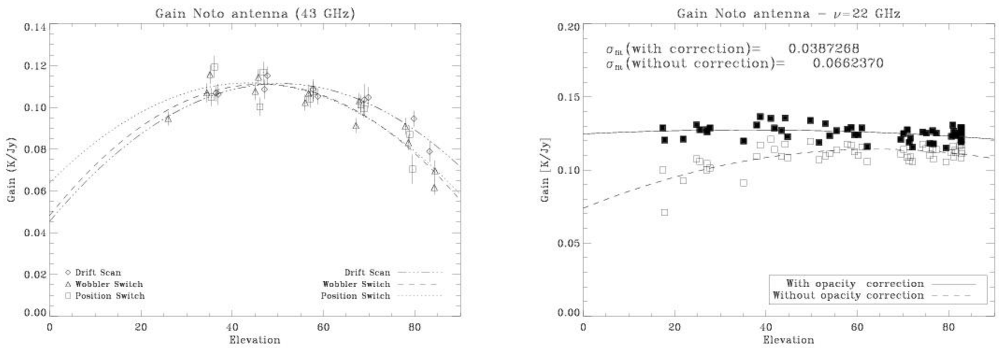

Fig. 3. Left panel: gain measures at 43 GHz for the different acquisition methods analyzed. Right panel: gain curves of the Noto antenna at 22 GHz with (filled symbols) and without (open symbols) atmospheric corrections.

Table 1. Antenna performance for different acquisition modes.

ν	Gain	σ (pos. sw.)	σ (wob. sw.)	σ (scan)
GHz	K/Jy	Jy	Jy	Jy
5	0.17	0.020	0.040	0.160
8.4	0.14	0.030	–	0.120
22	0.12	0.300	0.200	–
43	0.10	0.170	0.130	0.370

on source preceded and followed by 1 second of integration off-source. Each data point represents an average over 20 minutes.

All the measurements are corrected for atmospheric extinction. To estimate it, we repeated several times a series of tipping scans at elevations ranging between about 20° and about 80°, covering a range of sec(z) from 1.01 to 3. In Fig. 3 (right panel) we show the effect of the atmospheric extinction at high radio frequencies, by drawing the 22 GHz gain curves before and after correcting for the atmosphere.

In Table 1 we list the measurement errors for all the observing modes. It is clear that the wobbler switch mode offers a better performance than the other modes as the observing frequency increases. This is due to the shorter delay between the ON and OFF measurements, which allows a more precise sky subtraction. This delay could be further reduced, since the elapsed time is mostly due to communication between the field system computer and the subreflector.

The drift scan mode shows in general higher errors because it suffers from the slowness of the scan process and, at higher frequencies, from the inability to have higher acquisition rates. We expect to obtain better performance after the implementation of the RA rate setting command in the guide program and by using a digital integrator which allows a higher acquisition rate.

Despite the limitations mentioned above, our results show that the Noto radiotelescope capability to observe at frequencies up to 45 GHz might be used as a first stepping stone for those projects which will have their natural prosecution and completion with the SRT.

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